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Commercial Crew Program
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Crew Transportation Operations Standards

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1.0 Introduction

Under the guidance of processes provided by *Crew Transportation Plan* (CCT-PLN-1100), this document, with its sister documents, *Crew Transportation Technical Management Processes* (CCT-PLN-1120), *International Space Station (ISS) Crew Transportation and Services Requirements Document* (CCT-REQ-1130), *Crew Transportation Technical Standards and Design Evaluation Criteria* (CCT-STD-1140), and *ISS to Commercial Orbital Transportation Services Interface Requirements Document* (SSP 50808), provides the basis for a National Aeronautics and Space Administration (NASA) certification for services to the ISS for the Commercial Provider. When NASA Crew Transportation System (CTS) Certification is achieved for ISS transportation, the Commercial Provider will be eligible to provide services to and from the ISS during the services phase of the NASA Commercial Crew Program (CCP).

Management processes for review, verification, and validation of operations practices and products will adhere to the same principles of informed risk management used in the design and production of integrated space vehicles and systems.

Every mission exposes the flight crew to risk, and the execution of the mission must balance those risks with the consequences of loss of the mission objectives (such as the incremental risk of repeating the mission or impacts to ISS operations). Effective real-time launch countdown and flight operations must inherently address the ability to make timely and informed decisions to continue or terminate a mission based on the full understanding of the immediate and future risks.

1.1 Purpose

This document provides details of NASA expectations for operational products, processes, and facilities that are required by CCT-PLN-1120. All of the standards specified in this book are listed as items that *should* be performed, indicating that they are best practices. As part of the verification of the CCT-PLN-1120 operations requirements, NASA will perform reviews of the Commercial Provider's operations, processes, products, and facilities as described in this document. These reviews may consist of observation of operations, observation of training, inspection of facilities, inspection of tools, documentation, or testing.

NASA encourages the Commercial Provider to seek new innovative and cost effective methods for operations. This document is not meant to imply that the Commercial Provider should perform operations in the same manner as NASA's past or present techniques. In order to allow maximum flexibility and innovation to the Commercial Provider, the standards in this document may be implemented in numerous ways. For example, procedures must meet standards such as being validated in a test environment, use a consistent format, and clearly identify hazardous steps; however, the specific format and means of storing the procedure (electronic versus printed) is left to the Commercial Provider. During joint operations with the ISS, more specific standards must be followed such that joint products adhere to ISS standard formats and are compatible with ISS displays and controls. Therefore, there exists a subset of standards and practices that apply to working jointly with the ISS and these are documented in JSC-35089 *Visiting Vehicle Operations Document*, referenced in the *ISS to Commercial Orbital Transportation Services Interface Requirements Document* (SSP 50808).

The operations concept for the CTS will influence the design of flight hardware and ground architecture, therefore, these standards should be considered in the design phase of human space flight transportation systems.

1.2 Verb Application

Throughout this document set, *will* is used in a statement of fact, declaration of purpose, or expected occurrence; *shall* is used for binding requirements that must be verified and have an accompanying method of verification; and *should* denotes a statement of best practice.

1.3 Precedence

In the event of a conflict between the text of this document and references cited herein (listed in Section 2.0), the text of this document takes precedence. The exception to this statement is for SSP 50808, which takes precedence during arrival, docked, and departure operations. Nothing in this document supersedes applicable laws and regulations, unless a specific exemption has been obtained.

1.4 Delegation of Authority

This document was prepared by NASA's CCP, and will be maintained in accordance with standards for CCP documentation. The CCP is responsible for assuring the definition, control, implementation, and verification of the requirements identified in this document.

2.0 Reference Documents

These documents represent “best practices” for human space flight operations. The Commercial Provider may refer to these documents when designing the operations architecture and creating operations products.

Document Number	Revision	Title
CFR Title 14: Aeronautics and Space, Part 460		<i>Human Space Flight Requirements, FAA Draft Requirements, Part 460, § 460.5 Crew Qualifications and Training</i>
DA-WI-16	Rev. E	<i>Mission Operations Directorate Space Flight Personnel Certification Plan</i>
JSC 07268A		<i>Human Space Systems Operational Design Criteria Manual</i>
JSC-29229 (ISS) JSC-26843 (STS)		<i>Flight Control Operations Handbooks</i>
JSC-35089		<i>Visiting Vehicle Operations Document</i>
NASA/SP-2010-576		<i>NASA Risk-Informed Decision Making Handbook</i>
NASA-HDBK-8739.18		<i>Procedural Handbook for NASA Program and Project Management of Problems, Nonconformances, and Anomalies</i>
NPR 8621.1B		<i>NASA Procedural Requirements for Mishap and Close Call Reporting, Investigating, and Recordkeeping</i>
NPR 8705.2B		<i>Human-Rating Requirements for Space Systems (w/change 1 dated 12/7/2009)</i>
NSTS 12820		<i>Space Shuttle Operational Flight Rules, Volume A, All Flights</i>
NSTS 16007		<i>Shuttle Launch Commit Criteria and Background</i>
S0018.100		<i>Adverse Environment and Lightning Monitoring at LC-39</i>
S1025.100		<i>Flight and Ground Crew Emergency Egress/Escape Test</i>
SSP-50254	Rev P	<i>Operations Nomenclature</i>
SSP-50808		<i>ISS to Commercial Orbital Transportation Services Interface Requirements Document</i>

3.0 Operations Planning

Operations planning is a set of processes that result in operational products that support the assembly/integration/test, launch preparation and countdown, launch and mission execution, and post-flight recovery of the spacecraft. Operations products consist of plans and processes, analyses, procedures, process schedules, facilities, and supporting information developed prior to the execution of operations.

The content listed below should be included in the operational products developed by the Commercial Provider. Specific standards for this content are documented in subsequent sections of this document. Those standards should be met in whatever set of products the Commercial Provider chooses to use in certifying and operating the CTS. This list of content is not meant to be a formal list of deliverables, but is meant to convey to the Commercial Provider the typical artifacts that should be reviewed to evaluate proposed Commercial Provider operations products.

Operations Product Content	Description and Purpose
Mission Manifesting	Content that provides the following information about upcoming missions: expected launch/landing date, assigned flight crew, high-level mission objectives, flight cargo complement, assigned hardware elements (such as Spacecraft, engines, Launch Vehicle, flight suits), mission unique requirements, Government Furnished Equipment (GFE), NASA-provided supplies, logistics, etc.
Flight Design	Content that provides the detailed launch/on-orbit and re-entry trajectory, including planned maneuvers to achieve that desired trajectory. A process should also exist to allow for analyzing and changing the trajectory in near real-time based on off-nominal situations.
Nomenclature Definition	Content that defines operational nomenclature of major spacecraft components to ensure consistent communications, both verbal and written, regarding the operation of the spacecraft. Operations products and crew/ground displays utilize this nomenclature for components. This nomenclature is used in ground test procedures as well.
Operations Procedures	Content that contains the detailed steps required to execute nominal and off-nominal activities during the assembly/integration/test phase of ground processing, launch, the on-orbit mission, landing and crew/cargo recovery.
Vehicle/Crew Timelines	Content that provides schedule information about major activities, leading up to launch, during on-orbit operations, and immediately following landing.

Facilities and Ground Monitoring/Control Systems	Facilities needed to conduct pre-launch and flight operations and products that allow operations personnel to monitor vehicle data (e.g. telemetry displays, plots, event logging tools), issue control commands to the vehicle and plan and execute operations.
Flight Rules	Content that defines operational authority, hardware design limits, and human limitations to which operations must adhere during terminal pre-launch operations, flight operations, post-flight recovery operations, including operational controls to hazards and pre-defined decisions to take in off-nominal or contingency situations.
Launch Commit Criteria	Content that defines operational authority and system performance criteria of the CTS (including ground systems) necessary to commit the CTS to launch. This content includes operational controls to hazards and pre-defined decisions for off nominal and contingency situations.

3.1 General Operations Standards

All of the operations content developed as part of the planning process should follow these standards:

- a. Operations products should be made readily available to operations personnel and flight crew during development, ground processing, mission execution and recovery operations (from the perspective of spacecraft configuration for rescue).
- b. Operations products should be configuration managed. After validation and approval, operations products should be controlled through the Commercial Provider's approved configuration management to ensure the accuracy and currency of the products for mission use. Production, design changes, accumulated training and flight experience, or process improvements to the integrated space vehicle or other elements of the CTS, may require changes to previously validated operations products. These changes may be flight-specific configuration changes or incremental, permanent changes.
- c. A process should be established to ensure that hardware/software design changes are clearly communicated to the operations team. The process should also ensure that timely updates are made to timelines, procedures, training, and other operations products to account for these changes.
- d. All operations products that involve flight hardware, software or facilities should use a "test like you fly" approach, where appropriate.

3.1.1 General Operations Standards Assessment

NASA will review the Commercial Provider's configuration management process for operational products and related documentation that outlines standards for the development of operations products and processes. NASA will also observe the implementation and use of these standards during ground processing, training exercises such as simulations, and real-time operations. The emphasis of this review will be to ensure that there are adequate processes in place to generate and maintain a complete set of

high-quality operations products that will ultimately provide for consistent and safe spaceflight operations.

3.2 Standards for Mission Manifesting

Mission manifesting decisions require close coordination with multiple external entities, including NASA, launch/landing sites, the Federal Aviation Administration (FAA), and others. A process should be developed to ensure that all mission manifesting decisions are coordinated with these external entities and clearly communicated to all affected organizations and personnel. The process should integrate with existing NASA manifesting activities utilizing a timeframe consistent with those activities. Furthermore, changes to the flight's cargo complement may be requested by NASA at a late date in response to real-time events. The mission manifesting process should:

- a. Include expected launch/landing dates, assigned flight crew, high-level mission objectives, and mission requirements.
- b. Ensure both launch and return cargo mass properties, volume, power, and science objectives have been accommodated and the integrated vehicle has been verified to support this cargo.
- c. Ensure additional assigned hardware elements (such as spacecraft, engines, launch vehicle, flight suits) have been accounted for through a configuration management system that identifies any changes from the baseline manifest.
- d. Identify flight unique ground support requirements for the mission or cargo, cargo arrangement, GFE, NASA-provided supplies, and logistics.
- e. Include flexibility to accommodate late changes due to unforeseen events such as weather, on-orbit failures that require changing the cargo sent to or returned from ISS, range scheduling issues or other such circumstances.

3.2.1 Mission Manifesting Process Assessment

NASA will review the mission manifesting processes and audit the mission manifesting products.

3.3 Standards for Flight Design

3.3.1 Mission Trajectory Analyses Process

Pre-mission trajectory analysis should be performed to ensure that safety and mission requirements can be successfully met. These requirements include, but are not limited to, performance, constraint, and dispersion characteristics that influence or limit trajectory design and CTS certification requirements. This process should include:

- a. Design and analysis of the nominal and off-nominal trajectories flown by the integrated space vehicle, vehicle elements, and jettisoned or expended components during the ascent, orbit, rendezvous, re-rendezvous, departure and re-entry phases of flight under nominal, dispersed, and pre-determined failure conditions.
- b. Satisfaction of mission, hardware, and software constraints.
- c. Provisions for incorporating changes to mission requirements into revised analyses.
- d. Coordination as appropriate to meet all other regulatory requirements for launch.
- e. Pre-launch Range clearance and orbital collision avoidance.

3.3.2 Mission Design Analyses

To ensure a mission is operated safely, mission design analyses should:

- a. Assess separation from the launch vehicle and separation of jettisoned or expended components during all flight phases to ensure that recontact does not occur.

- b. Analyze all operations within proximity of another spacecraft to ensure safety of relative motion, including off-nominal events, breakouts, etc.
- c. Ensure that trajectory plans allow for converged orbit determination prior to targeting and executing subsequent maneuvers.
- d. Assess nominal and backup deorbit and landing opportunities.
- e. Analyze the communication coverage and availability of ground and orbital assets.
- f. Predict splashdown point or landing site, assess probable climatological conditions at the site, and determine the ability to dispatch rescue forces and rescue equipment for off-nominal landing locations.
- g. Determine public and mission essential personnel safety risks for launch, ascent, aborts, and re-entry, including disposal of non-recoverable elements and coordinate with appropriate responsible external entities (e.g. FAA, launch range, etc.).
- h. Ensure the design provides continuous abort coverage throughout the mission.
- i. Be performed with math models that include sufficient dispersions to assure that trajectory-driven mission objectives and safety constraints (e.g., rendezvous, re-entry, etc.) are not compromised.
- j. Provide for the capability to assess trajectory changes and deviations in near real-time and to develop alternate trajectory plans as required to ensure crew safety and/or mission success.

3.3.3 Consumables and Resources Analyses Process

Analyses should be generated for propulsive and non-propulsive consumables and onboard resources used by the integrated space vehicle and flight crew. The intent of these analyses is to:

- a. Determine the minimum required on-orbit propellant, plus reserves, required to support all nominal and off-nominal trajectories flown by the integrated space vehicle during the ascent, orbit, rendezvous, re-rendezvous, departure, and re-entry phases of flight under nominal, dispersed, and pre-determined failure conditions, including dispersions deemed highly probable and/or critical to flight crew and integrated space vehicle safety or high-priority mission objectives.
- b. Provide consumables loading profile and integrated space vehicle mass properties data to ensure the integrated space vehicle is operated within capability/certification limits for the duration of the mission.
- c. Assess and manage propulsive consumables profile and integrated space vehicle mass properties with respect to nominal mission plan and abort execution.
- d. Assess and manage on-orbit power and life support generation and resource demand for flight crew and vehicle systems based on mission profile, as required.
- e. For joint operations, track and update analyses based upon consumables and resources that are transferred to/from another docked spacecraft, if applicable.

3.3.4 Aborts Planning

Aborts are highly integrated events that may involve the launch vehicle, spacecraft, flight crew, operations personnel, ground facilities, and external entities. Aborts are a response to credible, life-threatening hazards which occur or could occur despite design mitigations and preventative measures and preclude continuance of the current mission plan. Abort planning should:

- a. Account for abort execution in all mission phases.
- b. Address roles and responsibilities of the flight crew and operations personnel.

- c. Provide for coordination of rescue and recovery assets, including joint development of contingency plans and operations protocols with external entities (e.g. NASA, FAA, State Department, DOD, Local Emergency Responders, etc.).
- d. Clearly identify any flight or ground hardware or software failure modes that could initiate an abort.
- e. Clearly identify any manual or automatic aborts and abort thresholds or limits that can be changed, initiated, or inhibited manually by the flight crew or remotely by operations personnel.
- f. Identify the operations required to recover from an aborted rendezvous and subsequent actions needed to re-attempt the rendezvous.
- g. Clearly define the failure modes, systems configurations and dispersion protection levels, or other relevant criteria against which abort performance is analyzed for purposes of certifying the abort system operation.

3.3.5 Flight Design Standards Assessment

NASA will review the flight design processes, tools, and analyses, the consumables budgeting process, and the abort planning. NASA will also review any tools used in real-time or near real-time to assess or alter vehicle trajectory. NASA will also observe simulations to verify operations personnel and flight crew have adequate situational awareness and capability to safely and accurately fly nominal and off-nominal trajectories and make changes to the trajectory as needed to account for perturbations, dispersions, off-nominal situations and other events.

3.4 Standards for Nomenclature Definition

In order to provide consistent terminology across the CTS elements for operational use, a standard operational nomenclature should be developed.

3.4.1 Standards for Nomenclature Definition

The CTS should identify how launch vehicle and spacecraft components will be labeled and referred to in operational documentation, including procedures. This operational nomenclature should be consistent in ground test procedures to minimize confusion across various phases of ground processing, launch, and mission phases. In some cases, this nomenclature may already be defined by existing components (e.g. existing launch vehicle nomenclature). The intent is not to change this existing nomenclature, but the Commercial Provider should still list these in the nomenclature definition to ensure operations personnel use the same terminology and to ensure it does not conflict with other vehicle terminology. The nomenclature list should be easily accessible to operations personnel who develop operational documentation. The list should also take into consideration the nomenclature used by ISS and attempt to avoid conflicts with this existing nomenclature as much as possible. The ISS operations nomenclature definition can be found in SSP-50254 or in the operations nomenclature database at <http://www.nasa.gov/centers/johnson/slsd/about/divisions/hefd/project/op-nom.html>.

3.4.2 Nomenclature Definition Assessment

NASA will review the Commercial Provider's process for development of an operational nomenclature standard and audit the documentation or database that stores the standard nomenclature. NASA will also observe the Commercial Provider's use of operations nomenclature and adherence to their standards during training, simulations and other activities.

3.5 Standards for Operations Procedures

Validated operations procedures are fundamental for successful operations. Defective procedures can lead to errors or omissions that can endanger the mission or the crew's safety. The generation and maintenance of procedures is critical to ensuring ground and flight operations occur in a consistent high-quality manner.

3.5.1 General Standards for Procedures

All procedures, whether developed for ground operations, in-flight operations, recovery or support of rescue should follow these general standards:

- a. Procedures should be validated prior to use in operations. Validation of procedures may include human-in-the-loop testing, real or simulated flight or ground hardware, operational or programmatic simulations, etc. Validation of procedures involving software should utilize real flight (or ground) software to the greatest extent practical.
- b. Procedures should address nominal operations, as well as off-nominal and emergency scenarios, which have been identified by test, analysis, or system experience, or which are determined to be safety critical based on likelihood or resulting consequence.
- c. Procedures should include placards, cautions, warnings, or other notes when a hazardous operation or procedure affects or could affect a safety-critical system or the safety of personnel, the public, or the environment.
- d. Procedures should explicitly state when Personal Protective Equipment (PPE) is required to perform an operation, task, or procedure.
- e. Procedures should be written in a standard Commercial Provider-defined format, consistent among CTS elements to the greatest extent possible, to facilitate ease of use by operations personnel and flight crew, and adhere to the nomenclature standard.
- f. Procedures should verify hardware is within the life-cycle and/or shelf-life limits and will remain so throughout ground processing and mission execution (e.g., ordnance, batteries, paints, soft goods, sealants, desiccants, etc.).
- g. Procedures should verify constraints prior to performing a task.

3.5.2 Standards for Ground Operations Procedures

Ground operations procedures are designed to protect personnel, flight hardware, and facilities during the assembly/integration/test, launch preparation, launch countdown, post-launch, and post-landing phases of a mission. All ground operations procedures should:

- a. Verify critical skills/certifications and task team readiness of personnel required to perform tasks, which may include medical support for hazardous testing with NASA crew.
- b. Maintain/verify the integrity of the flight hardware preserved within CTS certification while interfacing with all Ground Support Equipment (GSE) and facility systems, and account for natural and induced environments encountered throughout the handling/transportation operations, assembly/integration/testing, pre-launch processing, launch operations phases, and post-landing (if flight hardware is planned to be reused).
- c. Include instructions for the reconfiguration of flight hardware (e.g., rotating orientation).
- d. Include instructions for installation and removal of non-flight hardware on or into the launch vehicle or spacecraft (e.g., platforms, protective covers, remove before flight tagged items, non-flight switch covers, etc.).
- e. Verify ground hardware readiness prior to continuing into subsequent phases of processing.
- f. Support processes for metrology and other critical support activities and ground related records.

- g. Include instructions for test, checkout, power on/off, and monitoring.
- h. Include instructions for handling, storing, sampling/testing, and servicing of commodities of the CTS (e.g., fuel, oxidizer, helium, nitrogen, etc.).
- i. Configuration accounting and verification of requirements and procedures
- j. Photograph closed-out areas and final configuration.
- k. Include emergency instructions for launch vehicle and spacecraft safing for any hazardous operation or emergency power down procedures.
- l. Include vendor specific support and maintenance plans.
- m. Include sufficient reference to engineering drawings and photographs where drawings/photographs are needed for clarification or orientation.
- n. Identify and account for ground and flight crew access and handling (i.e. protective covers, guards, etc.)
- o. Include handover plans of flight crew between NASA and the Commercial Provider for pre-launch and post-landing.
- p. Include adverse weather plans (e.g. lightning retest, hail, high winds).
- q. Define rules governing handoff of authority or control from one CTS element to another that:
 - 1) Clearly identify roles and responsibilities of each party involved in the handoff.
 - 2) For the receiving party, clearly define and document the current configuration including any incomplete or unplanned work at the time of the handoff.
- r. Ensure successful assembly/integration/test ground procedures by including the following:
 - 1) Flight element mating and interface testing.
 - 2) Inventory assignment/distribution process and records which provide adequate control and traceability of critical parts and materials from the source to the final “as built” configuration.
 - 3) Include instructions for the inspection of the flight hardware prior to, and after, any handover transaction between CTS elements occurs.
- s. Ensure successful launch preparation and countdown by including the following:
 - 1) Process to prepare and safely operate the launch site prior to and after a launch.
 - 2) Timeline for execution of operations.
 - 3) Cargo installation or stowage, logistics, and pre-launch maintenance of cargo.
 - 4) Updated weather reports as required.
 - 5) Launch readiness polling process (e.g. Range, Program Management, Flight Crew, Technical Authorities, weather).
 - 6) Execution plan for launch countdown, scrub, and recycle.
 - 7) Closeout crew preparation and execution.
 - 8) Plan for safely entering blast danger area after hazardous commodity loading on launch day (e.g., control switching, configuration monitoring and visibility, restricted access control).
 - 9) Flight crew preparation (e.g., pre-flight launch countdown and simulations, launch day pre-flight briefings, ingress, etc.).
 - 10) Contingency operations (e.g. egress modes, aborts).
 - 11) Fault detection and response.
 - 12) End-to-end verification of all communication and command interfaces.
 - 13) Establishing and maintaining communications with the flight crew, spacecraft, operations personnel, and external stakeholders.
 - 14) Remote commanding of the integrated space vehicle (crewed or uncrewed).
 - 15) Telemetry processing and management.
- t. Ensure successful flight crew and cargo recovery by including the following:

- 1) Timeline of events.
- 2) Nominal and off-nominal post-landing spacecraft safing (splashdown/touchdown) events.
- 3) Post-landing ground service provisions prior to crew and cargo off-load.
- 4) Flight crew egress and post-egress flight crew assessments.
- 5) Plans to support post-landing medical operations or medical contingencies with the flight crew.
- 6) Plans to support post-landing science and any special logistical needs.
- 7) Flight crew equipment and cargo removal.
- 8) Include instructions for the inspection of the flight hardware prior to, and after, any handover transaction between CTS elements occurs.
- 9) Plans for recovery of the spacecraft (if there are plans for reuse).
- 10) Contingency safing protocols for use by untrained first responders without specialized equipment and for use by specially-trained rescue personnel.

3.5.3 Standards for Flight Operations Procedures

Flight operations procedures for mission controllers and flight crew should encompass all aspects of final launch preparations, integrated space vehicle operations, and mission-specific tasks/payloads/experiments to safely and successfully execute missions from launch through post-landing safing and recovery. The procedures should follow these standards:

- a. Flight operations procedures should be consistent between flight crew and mission controller procedures to the greatest extent possible.
- b. Flight operations procedures should clearly designate who is to perform which actions, especially between flight crew and mission control personnel, as required. Identify if the action must be performed at a specific time or if the action is time-critical.
- c. Flight operations procedures should contain instructions for the flight crew to perform essential mission tasks and respond to emergency events (e.g. loss of cabin pressure, fire, contingency deorbit, etc.) if communication with mission control is lost.
- d. Emergency procedures onboard should be readily available and capable of being referenced when emergency environmental conditions exist, independent of the nominal display method, control systems, and power system.
- e. A process should exist for the generation or modification of procedures in real-time in the event a procedure error is found or an unexpected situation is encountered. This process should involve review by appropriate engineering teams and validation of the procedure on simulated or real flight hardware, if time permits.

3.5.4 Operations Procedures Standards Assessments

NASA will review documentation, tools and standards that define how ground and flight procedures will be generated, validated and updated. NASA will review a subset of ground and flight operations procedures. The emphasis of the review will be on the content provided and the operations personnel's ability to understand and execute required tasks during nominal and off-nominal scenarios. NASA will also observe the use of procedures by operations personnel during training, simulations and operations to ensure standards are exercised.

3.6 Standards for Vehicle/Crew Timelines

Vehicle/crew timelines, sometimes called flight plans, provide a framework of the nominal mission and select contingencies, including scheduled operation of flight hardware and software, mission objectives and events, attitude timeline, and flight crew activities. The plans should encompass the entire mission from launch countdown through ascent, orbit, docking, ISS-mated operations, and undocking, re-entry and landing through recovery.

3.6.1 Standards for Vehicle/Crew Timelines

Generic and mission-specific planning ground rules and constraints should be developed to provide the flight crew and operations personnel activity guidelines for generation of the mission timeline, including ground commanding. Effective flight plans should:

- a. Integrate mission objectives, flight crew task assignments, integrated space vehicle requirements, trajectory, consumables, and resource usage into an efficient and cohesive plan.
- b. Integrate operations timelines across all CTS elements.
- c. Provide a timeline of nominally scheduled mission events, spacecraft maneuvers, and attitude hold periods, including estimated durations for each, to be utilized for mission execution, as well as power and consumables analyses.
- d. Provide a list of flight crew activities and corresponding information, which may include, but is not limited to:
 - 1) Procedure references/callouts used to perform nominally scheduled tasks.
 - 2) Time constraints with context for overall schedule.
- e. Identify the availability of communication coverage to flight operations personnel.
- f. Designate flight crew and/or operations personnel responsible for each mission event, task, and command execution, if appropriate.
- g. Ensure that the timing of major events is coordinated to a standard reference time across all systems.
- h. Be created in a format which allows for revisions/replanning to occur in a timely manner.
- i. Utilize a scheduling constraints plan for managing the flight crew timeline (e.g., awake times, sleep cycles, pre- and post-sleep activities, meals, off-duty time, launch day, docking, entry day, etc.).
- j. Coordinate a joint timeline for those missions that dock with the ISS.

3.6.2 Vehicle/crew Timelines Assessment

NASA will review the Commercial Provider's timelines. An emphasis will be placed on the flight crew and mission controller's ability to understand what activities will be performed at any given time, to correctly identify the appropriate procedure to run and to update the timeline as necessary. NASA will also review any configuration management process and documented constraints used in generation of timelines.

3.7 Standards for Operations Facilities and Ground Monitoring/Control Systems

A part of the planning process should include the development of facilities and operations products needed for ground monitoring and control of the spacecraft. The facilities used in operations include those needed for prelaunch ground processing, recovery and for mission controllers to perform in-flight monitoring and control.

3.7.1 Standards for Operations Facilities

Operations facilities will ensure that mission critical infrastructure is protected, maintained, and kept in a state of readiness. All facilities used in operations should:

- a. Ensure appropriate security (access control) protocols are used to limit access to the facility and its critical infrastructure to only those personnel who are qualified. These security protocols should ensure that unauthorized personnel cannot have access to or damage flight hardware during ground processing or gain access to systems that would allow for unauthorized commanding of a spacecraft during flight.
- b. Ensure that sensitive data transmitted to and from the facility is secure and that unauthorized personnel cannot access private or critical information about the spacecraft or crew.
- c. Allow for maintenance of the facility without interruption to ongoing operations (e.g. coordinate planned outages, be able to perform equipment changeout during a flight by switching temporarily to a backup equipment set).
- d. Ensure that facility operations do not induce hazards into the flight hardware.
- e. Provide redundancy in critical systems to allow operations to continue despite ground component or system failures.
- f. Ensure that the facility can support flight-specific configuration changes.
- g. Provide documented organization interface agreements that define the responsibilities of external organizations that use or operate the facility and how those organizations work together.
- h. Provide operations personnel with near-real-time access to stored engineering data and telemetered/stored flight data for the launch vehicle and spacecraft. This data should be available to assess the health of the integrated space vehicle for launch countdown or the ongoing flight, to support troubleshooting during a mission or major test, to provide flight crew with additional integrated space vehicle insight, and to inform future flights.
- i. Ensure that data availability and integrity is maintained for operations personnel continuously and redundantly during a mission to protect for ground systems failure(s).
- j. Develop a plan that implements an integrated system architecture to capture, confiscate, and embargo all data for use in reconstruction of an accident or mishap. Coordinate this plan with the Contingency Action Plan (reference section 6.4).

3.7.2 Ground Control/Monitoring Systems

Mission operations infrastructure also requires operations products that may include configuration files, display definitions, settings and databases that provide the means for mission controllers to monitor data, send commands and plan/organize operations during the mission. The operations products that support ground monitoring and control should:

- a. Have a defined process to ensure that onboard flight software is synchronized with ground tools. For example, ensure that telemetry available on the ground matches telemetry generated by the vehicle.
- b. Be tested in an end-to-end environment that includes the facility, the integrated space vehicle(s) and/or a high-fidelity simulator, and other CTS elements.
- c. Have documented standards for software validation for any software that will be used to make mission-critical decisions, including any tools used by mission controllers to perform calculations necessary to the operation of the spacecraft.
- d. Have a qualification process for all planning tools, such as timeline/procedure viewers, messaging tools, software used to create or modify procedures in real-time, etc.

3.7.3 Facilities and ground monitoring/control systems products assessment

NASA will inspect operations facilities. NASA will also review any documentation that defines the process for generating, updating and testing products that are used as part of ground monitoring and control, such as telemetry displays, alarm engines, command databases and other such products. NASA will review documentation that describes how ground facilities interface directly with flight hardware. NASA will also observe the facility performance during training exercises and simulations. This review will ensure a clearly defined process that is configuration managed and ensures facilities and products used in ground systems are adequately tested before flight.

3.8 Standards for Launch Commit Criteria

The Commercial Provider should utilize launch commit criteria (LCC) to minimize the amount of real-time rationalization that is required when off-nominal situations occur during launch countdown. These LCCs contain several types of important information:

- a. Definition of authority and roles/responsibilities
- b. Supporting rationale and history for provided limits in the LCC
- c. Affected measurements/telemetry
- d. Time efficacy of the LCC
- e. Violation criteria of the LCC
- f. Justification for continuing launch countdown through a LCC violation
- g. LCC should constrain launch if a subsequent problem could result in crew or vehicle loss, or abort unless an assessment of subsequent problem likelihood and specific effects determines the condition is acceptable.

The Commercial Provider should ensure that the information listed above is readily available to operations personnel, whether in the form of a Launch Commit Criteria document or through other electronic or documented means. This material should adhere to the following expectations:

- a. Pre-determined decisions should be supported by analysis using validated methods or tools to ensure that all expected flight configurations are within the design limits of the CTS.
- b. Supporting rationale should be documented as applicable.
- c. These documents should be reviewed and approved by appropriate subject matter experts or other CTS personnel.
- d. A process should be developed to ensure that any violation of design/operational limits, operations controls or pre-defined decisions is tracked. Appropriate personnel, such as management or subject matter experts, should be made aware of any such violations through this process and impacts to other operations and/or hardware capabilities should be assessed and documented.

3.8.1 Standards for Launch Commit Criteria Assessments

NASA will review the structure and process for the generation and configuration management of LCC to ensure it contains adequate information to guide operator decision-making during launch countdown. A subset of LCC will also be reviewed.

3.9 Standards for Flight Rules

Flight rules are used to guide operational personnel. These flight rules contain several types of important information:

- a. Definition of authority and roles/responsibilities of operations personnel, control centers and flight crew throughout all mission operations.
- b. Design and operational limits of hardware and human limitations to which the operations team should adhere.
- c. Operational controls to hazards (e.g. power down a piece of equipment before mating cables to avoid a shock hazard).
- d. Predefined decisions as a response to off-nominal situations or as a criteria for continuing into the next phase of an operation or mission (e.g. go to continue the rendezvous if this computer fails). This also includes LCC that define the system capability and redundancy required to proceed with a launch.

The Commercial Provider should ensure that the information listed above is readily available to operations personnel, whether in the form of a flight rules document or through other electronic or documented means. This material should adhere to the following expectations:

- a. Predetermined decisions should be supported by analysis using validated methods or tools to ensure that all expected flight configurations are within the design limits of the CTS.
- b. Supporting rationale should be documented as applicable.
- c. These documents should be reviewed and approved by appropriate subject matter experts or other CTS personnel that provide data or constraints driving flight rules.
- d. A process should be developed to ensure that any violation of design/operational limits, operations controls or pre-defined decisions is tracked. Appropriate personnel, such as management or subject matter experts, should be made aware of any such violations through this process and impacts to other operations and/or hardware capabilities should be assessed and documented.

3.9.1 Flight Rules Standards Assessment

NASA will review the structure and process for flight rules generation and configuration management to ensure it contains adequate information to guide operator decision-making during flight. A subset of flight rules will also be reviewed.

4.0 Operational Controls

Operations products will employ structured and documented processes for ensuring safety, monitoring ground processing and mission progress, making informed decisions, and addressing situations outside of nominal planned events. These processes will include sufficient technical rationale based upon the best available analysis and understanding of CTS design and capabilities.

4.1 Operational Hazard Analysis and Procedural Mitigation

The approved hazard analysis process should identify operationally induced risks and the mitigation of identified risks through operational controls. A closed-loop process should be incorporated to verify that all hazards accepted on the basis of an operational control (e.g., flight rule, limit, or procedural control) are accurately reflected in the operations products.

The Operational Hazard Analysis and implementation of resultant procedural mitigations should:

- a. Identify and document operational hazards and operational controls for hazards, and ensure that hazards identified in hazard reports as having operational controls can be clearly linked to a specific operational product (e.g. procedure, flight rule, etc.).
- b. Identify accepted hazards that have no operational controls and document strategies to mitigate those hazards and maximize crew survival.
- c. Identify hazards for which an abort action is appropriate through systematic processes, such as fault tree analysis and Failure Modes and Effects Analysis (FMEA).
- d. Ensure that any hazards associated with or controlled by an operation are clearly identified (e.g., through physical placards or warning notes in a procedure) and cannot be changed or waived without approval per the Hazard Report approval process or section 6.2 Operations Management Plan.
- e. Ensure that the process allows for operational control implementors to modify or reject operational controls that cannot be implemented as written.
- f. Establish a verification process to ensure that all hazards accepted as operationally-controlled are implemented (e.g. procedures, flight rules and/or training) and in place to accomplish that control.
- g. Ensure that personnel who may be exposed to hazards or hazardous operations are appropriately trained and informed.
- h. Address perceived hazards brought forth by stakeholders or external partners.

4.1.1 Operational Hazard Analysis and Procedural Mitigation Assessment

NASA will review the Commercial Provider's documented process(es) for identifying and implementing operational controls to hazards. NASA will also review the implementation of all operational hazard controls. NASA will confirm that the implementation of operational hazard controls can be executed as planned through observation of training exercises such as simulations.

5.0 Operations Training

All personnel with safety critical or mission critical roles should be adequately trained and fully capable of performing their duties in a competent manner. Documented training plans should be established for flight crew and for each unique safety critical or mission critical position staffed by operations personnel. These training plans should culminate in a certification that is valid for a set period of time. Proficiency training and evaluation should be performed to renew certifications on a periodic basis. Industry standards may be utilized to fulfill some certifications (e.g. medical personnel) if applicable.

Training plans may consist of self-study/readings, classroom lessons, computer-based training, hands-on training with hardware, simulations, evaluations or other methods. Personnel who conduct training lessons or simulations should be certified to conduct these lessons.

The following standards should be employed for training all operations personnel and flight crew:

- a. Training programs should include evaluation standards for demonstrating student mastery of the subject material.
- b. Formal training records and evidence of satisfactory completion should be documented, maintained, and made readily accessible to ensure that necessary certification, licensing, or currency requirements are met prior to performance of safety and mission critical tasks.
- c. There should exist at least one training environment that includes high-fidelity hardware representations of the CTS and at least one that includes a high-fidelity functional representation of the CTS (i.e. operates as the real vehicle even if hardware does not exactly match the physical layout of the real vehicle). These capabilities might also be available in a single training facility. However, both capabilities are required for adequate flight crew training.
- d. Certification for joint operations (involving cooperative operations with another vehicle, program, or external organization) should include joint integrated simulations with the appropriate external organization(s) using a high-fidelity vehicle simulation. Joint integrated simulation capability may require the ability to connect a CTS vehicle simulator to the joint operation partner's simulators. Joint integrated simulations should cover nominal and off-nominal scenarios and the capability to conduct training in parallel with an ongoing mission should exist. For more information about conducting joint training with the ISS operations team, refer to JSC-35089, *Visiting Vehicle Operations Document*.
- e. Ensure ground simulations conducted for launch countdown and egress simulations are conducted using high-fidelity flight representative systems and functional representation of the CTS, including support services, as applicable.
- f. Identify or establish medical certification standards for safety critical positions. Medical standards should be consistent with comparable aviation or other applicable occupational standards or certifications appropriate for the criticality of the function and should be approved by qualified medical personnel. Medical certifications should be renewed on a periodic basis, the frequency of which is appropriate to a task or as otherwise recommended/required by standards established by the responsible medical authority.
- g. Ensure that training programs are updated to incorporate lessons learned from training, actual operations, and changes in hardware/software design, or changes in external interfaces, with a process for tracking these updates.
- h. Provide specific training for any events or objectives that are unique to a given mission (i.e. mission specific vs. generic training).

5.1 Flight Crew Training Standards

The amount of material presented to flight crews during training should contain at least the minimum operational knowledge and skill required to safely operate the integrated space vehicle while ensuring mission success without exceeding vehicle limitations. Training should condition flight crews to be able to:

- a. Use integrated space vehicle systems and procedures to accomplish the nominal planned mission objectives and any off-nominal responses expected by the flight crew for each mission.
- b. Use validated procedures to operate integrated space vehicle systems to isolate and safe anomalies.
- c. Take appropriate action for the second failure while considering implications of a previous failure.

While utilizing communications with the ground, crews should demonstrate proficiency with all three of the above criteria. Proficiency is realized when assigned crews possess the ability to locate and execute any procedure and operate all onboard systems, regardless of whether or not they have been exposed to the necessary operation during training. It is not required that every failure scenario be presented during training. Failure probability, operational frequency, and/or criticality may be the criteria for defining the scope of training provided to crews.

NASA provides a significant amount of spaceflight training to NASA astronauts. This training includes the following:

- Space History, Laws and Treaties and International Space Agreements
- Overview of Space Physiology, Radiation and Acoustics
- Fundamentals of earth and space science and spacecraft engineering
- Leadership skills, conflict and stress managements
- Fundamentals of Orbital Mechanics and Rendezvous
- Zero-G familiarization flights and flight training (using T-38 aircraft)
- CO2 Exposure Symptom Determination
- Water and Land survival training
- Field Medical Training
- Basic photography skills
- Space Flight Resource Management (i.e. Crew Resource Management)

The Commercial Provider should ensure any training provided to NASA astronauts that involves any subjects listed above is coordinated with NASA training teams to ensure consistency and reduce duplication. If non-NASA crewmembers will be flying onboard the CTS, the Commercial Provider should provide training to those crewmembers on any topics listed above that are relevant to their role in the flight.

Note that Flight Crew designations in this document are applicable to the CTS. ISS and Soyuz use similar designations. Designations assigned to a crewmember for a visiting vehicle are not necessarily the designation assigned to that crewmember while on ISS.

Training for all members of the flight crew should include:

- a. Spacecraft systems knowledge.

- b. Spacecraft habitability, including response to environmental/radiation hazards.
- c. Launch vehicle knowledge.
- d. Ground operations (integrated space vehicle and personnel interactions during the pre-launch timeframe, including emergency pad egress).
- e. Flight operations (integrated space vehicle and personnel interactions during the in-flight timeframe).
- f. Procedures for all critical functions that flight crew personnel may be expected to perform.
- g. Simulation training to practice nominal, off-nominal, and emergency mission activities, including joint operations.
- h. Use of medical kits and procedures, including interface of ISS medical equipment that could be brought into the CCT for a medical emergency.
- i. Flight crew familiarization with equipment and vehicle interfaces that provide crew members with opportunity to understand any differences between the training mock-ups and flight vehicle, train on any items for which there are not flight-like mock-ups, correct differences between flight procedures and spacecraft configuration.
- j. Launch countdown simulation where the flight crew and launch team interface in a launch dress rehearsal and the sequence of crew operations from suit-up through terminal countdown are evaluated.
- k. Familiarization with rescue operations and training for recovery operations, plans and equipment.
- l. Emergency procedures exercises for ensuring crew survival in the event of a mishap or contingency during any phase of the mission.
- m. Hands-on operation of the hardware and software interfaces that will actually be used during flight.

5.1.1 Pilot

The Pilot role is defined as persons authorized to operate and control the flight-critical functions of the spacecraft during flight. If there are two or more pilots aboard, one should be designated the Pilot-in-Command (PIC) or Commander. The Commander or PIC will:

- a. Be responsible at all times for safe operation of the CTS spacecraft and conduct of the crew and mission.
- b. Be responsible for the safety of the occupants of the spacecraft.
- c. Be the final authority to initiate action deemed necessary for flight crew safety.
- d. Assess flight crew readiness to execute the mission plan, safety procedures, and emergency responses.

5.1.1.1 Pilot Training

The Pilot training program should include development of training tasks to demonstrate proficiency and maintain currency in the following skills applicable to piloting the Commercial Provider's spacecraft:

- a. Operational knowledge of the integrated space vehicle design, dependencies, interfaces, capabilities, and limitations.
- b. Nominal and off-nominal systems and trajectory performance, which may require manual intervention or abort action, during any flight phase where crew response is possible.
- c. Autonomous operation of the integrated space vehicle with an awareness of resultant effects to minimize the risk to the public, ground facilities, on-orbit assets, and flight crew.
- d. Operation of integrated space vehicle subsystems in normal and degraded modes.
- e. Integrated space vehicle fault recovery.

- f. Integrated training with operations personnel for mission cognizance, team building, and establishment of communication discipline.
- g. All modes of control or propulsion, including any transition between modes and degraded modes, and the resultant changes to integrated space vehicle trajectory.
- h. Aircraft, simulator, or program training designed to simulate nominal and off-nominal spacecraft flight paths for any flight phase where manual piloting can affect safety of flight.
- i. Pilot-in-command of turbine-powered aircraft in United States air space.

5.1.2 Specialist Training

Specialists are flight crew personnel that will be trained to assist the Pilot(s) with operating the integrated space vehicle, managing integrated space vehicle systems as appropriate, or improving the crew resource management environment within the integrated space vehicle. Specialists will receive mission and task-specific training commensurate with their mission role, which should include:

- a. Assisting the Pilot(s) with successful completion of the nominal mission.
- b. Assisting the Pilot(s) with integrated space vehicle systems management and fault recovery.
- c. Assisting the Pilot(s) with off-nominal and contingency operations of the spacecraft.
- d. Mission-specific tasks, as appropriate, involving spacecraft and systems management, payload-specific operations, or running experiments.

5.1.3 Space Flight Participant Training

Space Flight Participants are flight crew personnel that serve no operational role or critical function in managing the integrated space vehicle or any integrated space vehicle subsystems. Space Flight Participants should be adequately trained in space flight physiological issues, spacecraft emergencies, response to hazards, egress, and habitability so as to not pose a safety risk to other members of the flight crew. Space Flight Participants are not authorized to operate and control the integrated space vehicle or to configure any integrated space vehicle subsystems except for the operation of only those subsystems and equipment necessary for their activities as space flight participant.

5.2 Operations Personnel Training Standards

These standards apply to personnel who have been assigned roles and responsibilities that ensure the safety and integrity of flight and ground hardware and software, flight crew, and the general public. Assignments include, but are not limited to, assembly/integration/test, launch preparation, launch countdown, pre-flight planning and product development, training of flight crews and operations personnel, integrated space vehicle and subsystem performance analysis, mission execution and operations support, and recovery support. Training for operations personnel should include, at a minimum:

- a. Instruction on and execution of all nominal and off-nominal operations, joint operations, and emergency procedures relevant to their roles and responsibilities.
- b. In-depth knowledge of all applicable flight and ground systems, data monitoring and analysis tools, and procedures that are primary to their assigned roles, responsibilities, and tasks.
- c. General knowledge of additional flight systems, procedures, processes, and tools utilized in, assembly/integration/test, launch, mission, and recovery operations that are not directly covered by, but may influence or affect, their assigned roles, responsibilities, and tasks.
- d. General knowledge of additional ground hardware systems, procedures, processes and tools utilized in, assembly/integration/test, launch, mission, and recovery operations that are not directly covered by, but may influence or affect their assigned roles, responsibilities, and tasks.
- e. Failure recognition and response.

- f. General knowledge of standard operations common to all missions (including integrated space vehicle(s), facility(s), and personnel interactions).
- g. Communication skills and protocol with other operations personnel, flight crew, and external organizations, if applicable.
- h. Simulation or supervised on-the-job training of critical procedures and events, if applicable.
- i. Proper physical and medical certifications for participants in hazardous and contingency operations.

5.3 Operations Training Standards Assessment

NASA will review the training plans the Commercial Provider will use to certify safety critical and mission critical operational positions, including the medical standards which are required for those positions. NASA will also review the Commercial Provider's plans for certifying student lessons, conducting those lessons, setting evaluation standards needed for demonstrating student progression/mastery, and evaluating resulting student performance. NASA personnel will observe flight crew and operations personnel lessons to ensure that those lessons meet the standards above. NASA will also review the Commercial Provider's plans for certifying and conducting ground processing mission critical and safety critical personnel lessons and the training plans that the Commercial Provider will use to certify those personnel for ground processing operations. NASA will also observe training exercises such as simulations to evaluate the adequacy of the Commercial Provider's training. NASA will also audit training and certification records to ensure personnel performing tasks have the appropriate certifications.

6.0 Operations Execution

CTS risks are mitigated through disciplined execution of operations. Execution of operations includes the ground processing, major facility or hardware tests, and the flight phases of a mission. The operations processes should employ a clear definition of authority, roles and responsibilities, and communication protocols that allow for informed decision-making and risk management. The process for execution of operations must remain flexible but documented or recorded, so that with sufficient evaluation and approval, the process can accommodate changes to the ground processing flow or integrated space vehicle flight plan, unplanned events, or integrated space vehicle anomalies. In order to ensure smooth operational execution, the Commercial Provider should consider the following mission execution needs:

Operational Execution Need	Description
Communication Plans	Ensure that communications utilize approved channels and that personnel who need to know information are informed about events or problems. Communication protocols should be consistent.
Operations Management Plans	Ensure that personnel understand the chain of command and the limits to their individual responsibilities. Also determines how, where and when key management personnel will meet and what key decisions about ground processing and the mission are expected to be elevated to higher management levels.
Real-time Analysis	Ensure that resources (personnel and tools) needed for analysis in real-time to support unexpected or unanalyzed configurations are available when needed.
Contingency Action Plan	Document a plan of action and communication in case of a mishap during mission operation.
Data Availability and Integrity	Ensure all data involved in operations is available to operations personnel and recorded for future review as needed.
Operations Personnel Access to Design Information	Ensure that design documentation and hazard reports documenting operational controls are available to operations personnel during ground processing and mission execution.

6.1 Operational Communication Plans

Effective operational communication processes are critical for ensuring proper flow of information to all CTS elements and maintaining situational awareness onboard the integrated space vehicle, among operations personnel, and with dependent external partners. Communication plans and protocols must encompass the entire life-cycle of the CTS processing and mission flows, and should address:

- a. Internal communication- Establish a communication hierarchy and protocol internal to the CTS. The hierarchy should define communication among CTS elements for managing ground

processing, and pre-flight planning among flight crew and operations personnel throughout the life-cycle of the CTS. The protocol should define methods and oral standards by which the communication among CTS elements will occur.

- b. External communication- Establish plans for communicating with external entities, such as NASA Program Management, Range Authority, FAA, external customers, STRATCOM, Search and Rescue (SAR) team, and others as appropriate.
- c. Joint operations- For joint operations with cooperative spacecraft or ground stations, the Commercial Provider should develop plans for coordinating or participating in communications among all participants. Some cooperative spacecraft, such as the ISS, or ground stations, such as Mission Control Center - Houston (MCC-H) and ground-based communications and tracking stations, already utilize well-established communication protocols. The Commercial Provider should adhere to established protocols and must be able to perform joint operations in a coherent, integrated, and effective manner.

6.1.1 Communications Plans Assessments

NASA will review the Commercial Provider's documented communications plans and standards. These plans will be assessed for consistent use of the communication protocol across all phases of ground processing and mission.

6.2 Operations Management Plans

An operations management structure should be developed for the CTS. This structure should include a definition of the authority and roles/responsibilities of all involved parties during the mission, launch countdown through crew recovery. These authority definitions should clearly state when decision-making authority is delegated to the mission operations team or flight crew and when decisions must be approved by the management team. See CCT-PLN-1100 and CCT-PLN-1200 for information regarding the Mission Management Team (MMT). For example, the mission management team may make a formal Go/No-go decision to proceed with the rendezvous after spacecraft launch and checkout but may delegate the Go/No-go decision for final approach to the mission operations team. The management structure should be documented and should:

- a. Assume responsibility for all significant management decisions involving CTS operations, including proceeding with a major test or granting authority to proceed to the next mission phase (e.g., Go/No-go for launch, docking, etc.) and state when such authority is delegated to others.
- b. Manage and coordinate the response to an anomaly, contingency event, or emergency.
- c. Manage the process for making an informed decision on acceptance of increased risk when departing from previously agreed-to operational controls, operational plans or integrated space vehicle limits.

6.2.1 Operations Management Plan Assessment

NASA will review the Commercial Provider's Operations Management Plan.

6.3 Real-Time Analyses

Analyses will be performed during mission execution to evaluate actual ascent and on-orbit spacecraft performance against pre-flight analysis products (i.e., trajectory, mission design, consumables, and resources utilization predictions). In addition, analysis may be required in certain off-nominal situations that were not envisioned before flight. These planned or unplanned analyses may require the support of

specialized personnel who are not otherwise designated as operations support team. There should be plans in place to ensure the appropriate personnel are available to be contacted by the operations team to support planned or unplanned real-time analyses within the needed timeframe. The necessary computational, test and analysis equipment and facilities must also be available to support real-time analysis.

Detailed spacecraft design data should also be readily available to operations personnel to assist in troubleshooting and resolving off-nominal situations and understanding spacecraft behavior. This data should be up-to-date and contain information about any late changes made to the spacecraft hardware or software.

If a test flight requires that certain objectives be analyzed and confirmed successful prior to proceeding with other test flight objectives on the same mission, a plan should be developed which describes what real-time analysis will be required to verify objectives are complete before proceeding with addition flight test events. Such a plan for any test flights that include ISS as a destination is called out in JSC-35089, *Visiting Vehicle Operations Document*. If a test flight does not use ISS as a destination, this plan should still be developed if the test flight will require real-time analysis to verify certain test milestones are successfully completed prior to proceeding with other test milestones.

6.3.1 Real-Time Analysis Plan Assessment

NASA will review the Commercial Provider's plans to have real-time analyses performed with personnel available during the mission execution. NASA will inspect the capability for operations personnel to readily access design data including as-flown hardware and software data.

6.4 Contingency Action Plan

A contingency action plan contains provisions for immediate protection/recovery of flight crew and operations personnel in the event of a mishap, emergency, natural disaster, or act of terrorism. The plan should provide notifications and coordinated interactions with other NASA or external Agency/Center Mishap Preparedness and Contingency Plans, as appropriate (for example, in the case of a launch using KSC or Eastern Range facilities).

At a minimum, the contingency action plan should:

- a. Document response plans and procedures for catastrophic events, ascent abort, emergency deorbit, or other scenarios beyond the scope of normal ground processing and mission operations plans to maximize the chances of flight crew survival.
- b. Include provisions to minimize losses and control public and environmental hazards, as well as for the immediate embargo of operations personnel, data, telemetry, and recovered hardware to ensure integrity of mishap information for coordinating an immediate mishap response.
- c. Identify the responsibilities of internal parties, the external organizations that must be notified, and any existing agreements with external entities for mishap response (such as NASA, SAR team, State Department, DOD, Intergovernmental Agreements, etc.).
- d. Address medical care of the flight crew and operations personnel for contingency operations emergencies, launch aborts, on-orbit events, or reentry and landings, including what major facilities nearby are pre-planned or designated contingency landing zones.
- e. Identify the requirements for seagoing and airborne craft supporting as first responders, and perform pre-coordination with facilities at the nearby ports. For example, this may include

aircraft in flight-ready status that can be called up to get any key/critical personnel or equipment, including medical, to a contingency or emergency site.

6.4.1 Contingency Action Plan

NASA will review the contingency action plan.

7.0 Anomaly and Lessons Learned Tracking and Resolution

7.1 Anomaly Tracking and Resolution

A closed-loop anomaly tracking and resolution process will be developed for ground processing and flight operations that identifies and resolves any hardware or software performance characteristic that is or may be inconsistent with operational or design expectations. These anomalies can include, but are not limited to, ground hardware or integrated space vehicle problems, operations issues, non-conformances, deficiencies, in flight anomalies, and ‘process escapes.’

The assembly/integration/test launch preparation, and recovery phases of ground processing should include an anomaly tracking and resolution process that identifies how anomalies are reported, tracked, investigated, and resolved. This process should address the following:

- a. Documentation of conditions detected during testing or operations that do not fall within the listed acceptance or rejection criteria of the procedure being performed.
- b. Identify whether non-conformance is effective for specific vehicle serial number or is applicable for additional vehicles in flow.
- c. Identify anomalies initiated on GSE or facilities that directly interface with flight hardware.
- d. Identify if non-conformance is a result of a faulty part or unexpected part failure.
- e. Any anomaly resolution that includes a hardware design change.
- f. Include an effectivity and rationale of acceptance for any anomaly that is not fully resolved through retest or replacement.
- g. Impacts to Ground Processing and Operational Constraints – Any impacts to on-going or upcoming operations, including constraints that have been or need to be established to protect the crew, integrated space vehicle systems, ground hardware, or software, as a result of the anomaly will be documented. The establishment of temporary placards or constraints should be documented.
- h. Anomaly report history should be readily available to operations personnel in order to assist with training and allow them to understand if an anomaly on a spacecraft has been previously seen and what response was taken during that time.
- i. Resolution process should include incorporation of process improvements, lessons learned, and replacement or retest of failed hardware/software prior to closure.
- j. Any long-term impacts to hazard analysis (new causes, changes to controls or verifications, etc.) need to be reported back to the hazard analysis authors for hazard analysis impact evaluation, updates and safety community approval.

During the launch and mission phases, anomaly tracking and resolution process should identify how anomalies are reported, tracked, investigated, and resolved. This process should address the following:

- a. Immediate response – Through established LCC, flight rules, training, procedures or other plan(s), the process should provide documented guidance for an immediate response required from flight crew, operations personnel, or automated software to maintain the integrated space vehicle and related ground hardware in a safe state, if possible. This response will account for:
 - 1) Short-term impacts to the CTS, hardware, software, flight crew, and operations personnel.
 - 2) Short-term corrective actions to resolve and/or mitigate the impacts associated with the anomaly.
 - 3) Measures for preventing or minimizing recurrence of the anomaly.
 - 4) Any other actions or controls required for safety or mission assurance.

- b. Long-term recovery actions required – The process will provide guidance to determine and document whether any actions, beyond those already taken by the flight crew, operations personnel, or automated software, are required to reduce the risk to the CTS or to restore systems to nominal or degraded functionality. The long-term action may involve recommended hardware/software changes for future flights to correct the anomaly.
- c. Root cause – The process should determine the root or probable cause(s) of an anomaly in order to determine if any future changes to design or operations are required.
- d. Safety hazards and risks – The process will document the current and potential safety hazards and risks associated with the anomaly and any recovery actions already taken or being considered.
- e. Impacts to mission operations and operational constraints – Any impacts to on-going or upcoming operations, including constraints that have been or need to be established to protect the flight crew or integrated space vehicle systems, hardware, or software, as a result of the anomaly will be documented. The establishment of temporary placards or constraints should be documented.
- f. Anomaly report history should be readily available to operations personnel in order to assist with training and allow them to understand if an anomaly on a spacecraft has been previously seen and what response was taken during that time.

7.1.1 Anomaly Tracking Process Assessment

NASA will review the Commercial Provider's anomaly resolution and tracking processes. NASA will also observe simulations and operations to ensure anomaly response and tracking are exercised per Commercial Provider's processes.

7.2 Flight Crew and Operations Personnel Debrief

A process should be established for debriefing the flight crew and the operations personnel after a mission. This debrief should provide the flight crew and operations personnel with a forum (parts of which may be confidential) for discussing activities and issues that occurred during a mission flow (encompassing pre-launch through post-landing), with appropriate program management, additional operations personnel, and medical participants in attendance. The flight crew debrief should address any issues observed in the mission and allow for personnel to provide recommendations to improve missions in the future. The scope of the debrief should be all-inclusive and discuss training, anomalies seen, recommended changes to products and procedures, etc.

These "lessons learned" should be captured and any actions resulting from them tracked to ensure improvements are made to products and processes as a result of the debrief. The lessons learned information should also be available to operations personnel as part of their training for future flights.

7.2.1 Debrief Process Assessment

NASA will review the Commercial Provider's proposed process for debriefing personnel and capturing/tracking lessons learned for future missions. NASA will observe debriefs and lessons learned forums/tracking tools to ensure processes are exercised as stated.

Appendix A: Acronyms

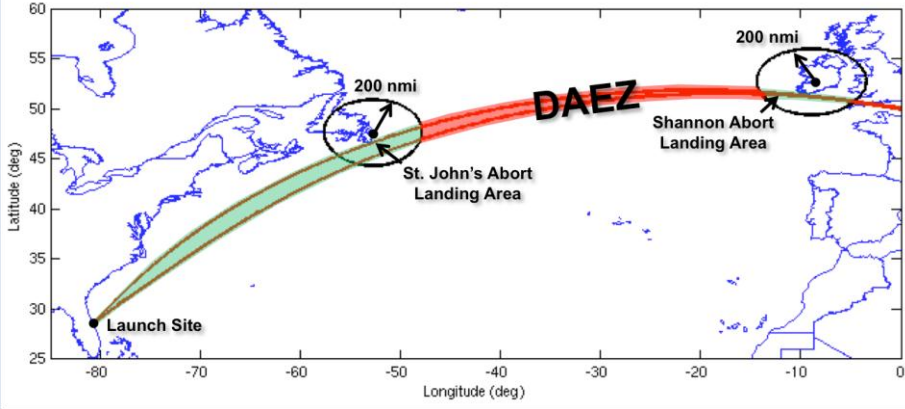
Acronyms	Phrase
CCP	Commercial Crew Program
CRM	Crew Resource Management
CTS	Crew Transportation System
DOD	Department of Defense
GFE	Government Furnished Equipment
GSE	Ground Support Equipment
FAA	Federal Aviation Administration
FMEA	Failure Modes and Effects Analysis
ISS	International Space Station
JSC	Johnson Space Center
KSC	Kennedy Space Center
LCC	Launch Commit Criteria
MCC-H	Mission Control Center – Houston
NASA	National Aeronautics and Space Administration
PIC	Pilot-in-Command
PPE	Personal Protective Equipment
SAR	Search and Rescue
UTC	Coordinated Universal Time

Appendix B: Definitions

Term	Definition
Abort	The forced early return of the crew when failures or the existence of uncontrolled catastrophic hazards prevent continuation of the mission profile and a return is required for crew survival.
Ambient Light	Any surrounding light source (existing lighting conditions). This could be a combination of natural lighting (e.g., sunlight, moonlight) and any artificial light source provided. For example, in an office there would be ambient light sources of both the natural sunlight and the fluorescent lights above (general office lighting).
Analysis	A verification method utilizing techniques and tools, such as math models, prior test data, simulations, analytical assessments, etc. Analysis may be used in lieu of, or in addition to, other methods to ensure compliance to specification requirements. The selected techniques may include, but not be limited to, task analysis, engineering analysis, statistics and qualitative analysis, computer and hardware simulations, and analog modeling. Analysis may be used when it can be determined that rigorous and accurate analysis is possible, test is not cost effective, and verification by inspection is not adequate.
Annunciate	To provide a visual, tactile, or audible indication.
Approach Ellipsoid	A 4 x 2 x 2 km ellipsoid, centered at the ISS center of mass, with the long axis aligned with the V-Bar.
Approach Initiation	The approach initiation is the first rendezvous maneuver during a nominal approach that is targeted to bring the vehicle inside the ISS approach ellipsoid (AE).
Ascent	The period of time from initial motion away from the launch pad until orbit insertion during a nominal flight or ascent abort initiation during an abort.
Ascent Abort	An abort performed during ascent, where the crewed spacecraft is separated from the launch vehicle without the capability to achieve the desired orbit. The crew is safely returned to a landing site in a portion of the spacecraft nominally used for entry and landing/touchdown.
Automated	Automatic (as opposed to human) control of a system or operation.
Autonomous	Ability of a space system to perform operations independent from any ground-based systems. This includes no communication with, or real-time support from, mission control or other ground systems.
Backout	During mission execution, the coordinated cessation of a current activity or procedure and careful return to a known, safe state.
Breakout	Any action that interrupts the nominally planned free flight operations that are intended to place the spacecraft outside of a threatening location to the cooperative vehicle. This may be an automated or manually executed action. For the ISS, the area within which a vehicle poses a threat to ISS is called the Approach Ellipse.
Cargo	An item (or items) required to maintain the operability of the ISS and/or the health of its crew, and that must be launched and/or returned.

Catastrophic Event	An event resulting in the death or permanent disability of a ground closeout or flight crewmember, or an event resulting in the unplanned loss/destruction of a major element of the CTS or ISS during the mission that could potentially result in the death or permanent disability of a flight crewmember.
Catastrophic Hazard	A condition that could result in the death or permanent disability of a ground closeout or flight crewmember, or in the unplanned loss/destruction of a major element of the CTS during the mission that could potentially result in the death or permanent disability of a flight crewmember.
Command	Directive to a processor or system to perform a particular action or function.
Communications Coverage	Communication coverage is defined as successful link availability for nominal ascent and entry trajectories.
Communications Link	A communication link is established, whereas the received commands and voice from the CVCC to the spacecraft and the transmitted health and status data, crew health and medical related data, voice, telemetry, and transmitted launch vehicle and spacecraft engineering data are received.
Consumable	Resource that is consumed in the course of conducting a given mission. Examples include propellant, power, habitability items (e.g., gaseous oxygen), and crew supplies.
Continental U.S. Airport	An airport within the continental United States capable of accommodating executive jet aircraft similar to the Gulfstream series aircraft.
Contingency	Provisioning for an event or circumstance that is possible but cannot be predicted with certainty.
Contingency Spacecraft Crew Support (CSCS)	CSCS is declared when the spacecraft crew takes shelter on the ISS because the spacecraft has been determined to be unsafe for reentry. In this case, a rescue mission is required to return the spacecraft crew safely.
Crew	Any human onboard the spacecraft after the hatch is closed for flight or onboard the spacecraft during flight.
Crew Transportation System (CTS)	The collection of all space-based and ground-based systems (encompassing hardware and software) used to conduct space missions or support activity in space, including, but not limited to, the integrated space vehicle, space-based communication and navigation systems, launch systems, and mission/launch control.
Critical Decision	Those technical decisions related to design, development, manufacturing, ground, or flight operations that may impact human safety or mission success, as measured by defined criteria.
Critical Fault	Any identified fault of software whose effect would result in a catastrophic event or abort.
Critical Function	Mission capabilities or system functions that, if lost, would result in a catastrophic event or an abort.
Critical Hazard	A condition that may cause a severe injury or occupational illness.
Critical Software	Any software component whose behavior or performance could lead to a catastrophic event or abort. This includes the flight software, as well as ground-control software.
Critical Software/Firmware	Software/Firmware that resides in a safety-critical system that is a potential hazard cause or contributor, supports a hazard control or mitigation, controls

	safety-critical functions, or detects and reports 1) fault trends that indicate a potential hazard and/or 2) failures which lead to a hazardous condition.
Critical (sub)System	A (sub)system is assessed as critical if loss of overall (sub)system function, or improper performance of a (sub)system function, could result in a catastrophic event or abort.
CTS Certification	CTS certification is the documented authorization granted by the NASA Associate Administrator that allows the use of the CTS within its prescribed parameters for its defined reference missions. CTS certification is obtained prior to the first crewed flight (for flight elements) or operational use (for other systems).
CTS Element	One component part of the overall Crew Transportation System. For example, the spacecraft is an element of the CTS.
Deconditioned	“Deconditioned” defines a space crewmember whose physiological capabilities, including musculoskeletal, cardiopulmonary, and neurovestibular, have deteriorated as a result of exposure to micro-gravity and the space environment. It results in degraded crewmember performance for nominal and off-nominal mission tasks.
Definitive Medical Care	An inpatient medical care facility capable of comprehensive diagnosis and treatment of a crewmember's injuries or illness without outside assistance—capable of care of Category I, II, and III trauma patients. Usually a Level I trauma center, as defined by the American College of Surgeons.
Demonstration	A method of verification that consists of a qualitative determination of the properties of a test article. This qualitative determination is made through observation, with or without special test equipment or instrumentation, which verifies characteristics, such as human engineering features, services, access features, and transportability. Human-in-the-loop demonstration is performed for complex interfaces or operations that are difficult to verify through modeling analysis, such as physical accommodation for crew ingress and egress. Demonstration requirements are normally implemented within a test plan, operations plan, or test procedure.
Docking	Mating of two independently operating spacecraft or other systems in space using independent control of the two vehicles' flight paths and attitudes during contact and capture. Docking begins at the time of initial contact of the vehicles' docking mechanisms and concludes when full rigidization of the interface is achieved.
Downrange Abort Exclusion Zone	A geographical region of the North Atlantic Ocean to be avoided for water landings during ascent aborts for ISS missions due to rough seas and cold water temperatures. The region is depicted in Figure B-1. The St. John's abort landing area includes the waters within 200 nmi range to St John's International Airport (47° 37' N, 52° 45' W). The Shannon abort landing area includes the waters within 200 nmi range to Shannon International Airport (52° 42' N, 8° 55' W). Note: The northern and southern bounds of the DAEZ in the ISS Mission DAEZ figure are notional, as these bounds are limited only by steering and cross-range performance along the ascent trajectory and are not formally constrained.

Downrange Abort Exclusion Zone Figure	 <p>Figure B-1 Ascent Downrange Abort Exclusion Zone</p>
Emergency	An unexpected event or events during a mission that requires immediate action to keep the crew alive or serious injury from occurring.
Emergency Egress	Capability for a crew to exit the vehicle and leave the hazardous situation or catastrophic event within the specified time. Flight crew emergency egress can be unassisted or assisted by ground personnel.
Emergency Equipment and Systems	Systems (ground or flight) that exist solely to prevent loss of life in the presence of imminent catastrophic conditions. Examples include fire suppression systems and extinguishers, emergency breathing devices, Personal Protective Equipment (PPE) and crew escape systems. Emergency systems are not considered a leg of failure tolerance for the nominal, operational equipment and systems, and do not serve as a design control to prevent the occurrence of a catastrophic condition.
Emergency Medical Services	Services required to provide the crewmembers with immediate medical care to prevent loss of life or aggravated physical or psychological conditions.
End of Mission	The planned landing time for the entire mission, including the nominal pre-flight agreed to docked mission duration.
Entry	The period of time that begins with the final commitment to enter the atmosphere from orbit or from an ascent abort, and ending when the velocity of the spacecraft is zero relative to the landing surface.
Entry Interface	The point in the entry phase where the spacecraft contacts the atmosphere (typically at a geodetic altitude of 400,000 feet), resulting in increased heating to the thermal protection system and remainder of the spacecraft exterior surfaces.
External Launch Constraint	Conditions outside the CTS provider's control, such as range weather constraints or faults with range or ISS assets, or weather constraints affecting abort rescue forces capabilities. Range weather examples include ability to visually monitor the initial phases of the launch for range safety, etc. Non-weather range constraints include range safety radar and telemetry systems availability, flight termination systems readiness, clearance of air, land, sea, etc.
Failure	Inability of a system, subsystem, component, or part to perform its required function within specified limits.

Failure Tolerance	The ability to sustain a certain number of failures and still retain capability. A component, subsystem, or system that cannot sustain at least one failure is not considered to be failure tolerant.
Fault	An undesired system state and/or the immediate cause of failure (e.g., maladjustment, misalignment, defect, or other). The definition of the term “fault” envelopes the word “failure,” since faults include other undesired events, such as software anomalies and operational anomalies. Faults at a lower level could lead to failures at the higher subsystem or system level.
Flight Configuration	The arrangement, orientation and operational state of system elements and cargo, vehicle cabin layout, flight software mode, and crew complement, clothing and equipment in the applicable mission or ground phase necessary in verification to evaluate the attributes called out in the requirement.
Flight Hardware	All components and systems that comprise the internal and external portions of the spacecraft, launch vehicle, launch abort system, and crew worn equipment.
Flight Operations	All operations of the integrated space vehicle and the crew and ground teams supporting the integrated space vehicle from liftoff until landing.
Flight Phase	A particular phase or timeframe during a mission is referred to as a flight phase. The term “all flight phases” is defined as the following flight phases: pre-launch, ascent, onorbit free-flight, docked operations, deorbit/entry, landing, and post-landing.
Flight Representative	<p>Description of a test-article used in verifications in which the attributes under evaluation are equivalent to the flight article.</p> <p>Example: Human-in-the-loop tests for spacecraft egress must use an equivalent cabin layout, seats and restraints, and hatch configuration and masses. However, the propulsion system does not need to be functional, as it is not under evaluation.</p>
Flight Rules	Established redline limits for critical flight parameters. Each has pre-planned troubleshooting procedures with pre-approved decisions for expected troubleshooting results.
Flight Systems	Any equipment, system, subsystem or component that is part of the integrated space system.
Flight Termination	An emergency action taken by range safety when a vehicle violates established safety criteria for the protection of life and property. This action circumvents the vehicles’ normal control modes and ends its powered and/or controlled flight.
Free Flight Operations	Onorbit operations that occur when the spacecraft is not in contact with any part of the ISS.
Ground Crew	Operations personnel that assist the flight crew in entering the spacecraft, closing the hatch, performing leak checks, and working on the integrated space vehicle at the pad during launch operations.
Ground Hardware	All components and systems that reside on the ground in support of the mission, including the Commercial Vehicle Control Center, launch pad, ground support equipment, recovery equipment, facilities, and communications, network, and tracking equipment.

Ground Processing	The work required to prepare the launch vehicle and spacecraft for mission from final assembly/integration/test through launch and resumes after landing for recovery of crew and cargo.
Ground Support Equipment	Any non-flight equipment, system(s), ground system(s), or devices specifically designed and developed for a direct physical or functional interface with flight hardware to support the execution of ground production or processing. The following are not considered to be GSE: <ul style="list-style-type: none"> Tools designed for general use and not specifically for use on flight hardware. Ground Support Systems that interface with GSE Facilities.
Habitable	The environment that is necessary to sustain the life of the crew and to allow the crew to perform their functions in an efficient manner.
Hazard	A state or a set of conditions, internal or external to a system, that has the potential to cause harm.
Hazard Analysis	The process of identifying hazards and their potential causal factors.
Health and Status Data	Data, including emergency, caution, and warning data, that can be analyzed or monitored describing the ability of the system or system components to meet their performance requirements.
Human Error	Either an action that is not intended or desired by the human or a failure on the part of the human to perform a prescribed action within specified limits of accuracy, sequence, or time that fails to produce the expected result and has led or has the potential to lead to an unwanted consequence.
Human Error Analysis (HEA)	A systematic approach used to evaluate human actions, identify potential human error, model human performance, and qualitatively characterize how human error affects a system. HEA provides an evaluation of human actions and error in an effort to generate system improvements that reduce the frequency of error and minimize the negative effects on the system. HEA is the first step in Human Risk Assessment and is often referred to as qualitative Human Risk Assessment.
Human-in-the-Loop Evaluation	Human-in-the-loop evaluations involve having human subjects, which include NASA crewmembers as a subset of the test subject population, perform identified tasks in a representative mockup, prototype, engineering, or flight unit. The fidelity of mockups used for human-in-the-loop evaluations may range from low-fidelity, minimal representation, to high-fidelity, complete physical and/or functional representation, relevant to the evaluation. Ideally, the fidelity of human-in-the-loop mockups and tests increases as designs mature for more comprehensive evaluations. Further information on human-in-the-loop evaluations throughout system design can be found in JSC 65995 CHSIP.
Human-System Integration	The process of integrating human operations into the system design through analysis, testing, and modeling of human performance, interface controls/displays, and human-automation interaction to improve safety, efficiency, and mission success.
Ill or Injured	Refers to a crewmember whose physiological and/or psychological well-being and health has deteriorated as a result of an illness (e.g., appendicitis) or injury (e.g., trauma, toxic exposure) and requires medical capabilities exceeding those available on the ISS and transportation to ground-based definitive

	medical care. Ill or injured crewmember performance for nominal and off-nominal mission tasks will be degraded.
Inspection	A method of verification that determines conformance to requirements by the use of standard quality control methods to ensure compliance by review of drawings and data. This method is used wherever documents or data can be visually used to verify the physical characteristics of the product instead of the performance of the product.
Integrated Operations	All operations starting at 90 minutes prior to the ISS Approach Initiation and lasting until the vehicle leaves the ISS Approach Ellipsoid on a non-return trajectory.
Integrated Space Vehicle	The integrated space vehicle consists of all the system elements that are occupied by the crew during the space mission and provide life support functions for the crew. The integrated space vehicle also includes all elements physically attached to the spacecraft during the mission. The integrated space vehicle is part of the larger space system used to conduct the mission.
Landing	The final phase or region of flight consisting of transition from descent to an approach, touchdown, and coming to rest.
Landing Site	<p>Supported Landing Sites: A fully supported site on a Continental U.S. land mass or waters directly extending from the coast with CTS recovery forces on station at the time of landing. The landing site zone extends through nominally expected dispersions from the landing site point.</p> <p><u>Designated Primary Landing Site</u> – A supported landing site-intended for landing at the time of spacecraft undock.</p> <p><u>Alternate Landing Site</u> – A supported landing site to which the spacecraft landing can be diverted in the event the deorbit burn is delayed.</p> <p>Unsupported Landing Sites:</p> <p><u>Emergency Landing</u> – Any unsupported site (land or water) arrived at due to critical failures that force immediate return and preclude landing at a designated primary or alternate landing sites.</p>
Launch Commit Criteria	Established redline limits for critical launch parameters. Each has pre-planned troubleshooting procedures with pre-approved decisions for expected troubleshooting results.
Launch Opportunity	The period of time during which the relative position of the launch site, the ISS orbital plane, and ISS phase angle permit the launch vehicle to insert the spacecraft into a rendezvous trajectory with the ISS (northerly launches only due to range constraints). The ISS is in-plane with the Eastern Range approximately every 23 hours and 36 minutes.
Launch Probability	The probability that the system will successfully complete a scheduled launch event. The launch opportunity will be considered scheduled at 24 hours prior to the opening of the launch window.
Launch Vehicle	The vehicle that contains the propulsion system necessary to deliver the energy required to insert the spacecraft into orbit.
Life-Cycle	The totality of a program or project extending from formulation through implementation, encompassing the elements of design, development, verification, production, operation, maintenance, support, and disposal.
Loss of Crew	Death or permanently debilitating injury to one or more crewmembers.

Loss of Mission	Loss of, or the inability to complete enough of, the primary mission objectives, such that a repeat mission must be flown.
Maintenance	The function of keeping items or equipment in, or restoring them to, a specified operational condition. It includes servicing, test, inspection, adjustment/alignment, removal, replacement, access, assembly/disassembly, lubrication, operation, decontamination, installation, fault location, calibration, condition determination, repair, modification, overhaul, rebuilding, and reclamation.
Manual Control	The crew's ability to bypass automation in order to exert direct control over a space system or operation. For control of a spacecraft's flight path, manual control is the ability for the crew to affect any flight path within the capability of the flight control system. Similarly, for control of a spacecraft's attitude, manual control is the ability for the crew to affect any attitude within the capability of the flight/attitude control system.
MCC-H Mission Authority	<ul style="list-style-type: none"> • MCC-H has authority to make final decisions regarding spacecraft operations, including but not limited to Go/No-Go decisions and safety of flight and crew(s). • Beginning with either ISS integrated operations, or 30 minutes before the first required ISS configuration or crew activity in support of the spacecraft on rendezvous (e.g., ISS attitude maneuver, appendage configuration, USOS GPS configuration), whichever comes first. • Ending with either the end of ISS integrated operations, or when ISS is not required to maintain its configuration (e.g., ISS attitude, USOS GPS configuration, or appendages in a configuration) to support the spacecraft, whichever comes later. • Applies anytime the spacecraft free-drift trajectory, including dispersions, is predicted to enter the ISS AE within the next 24 hours.
Mission	The mission begins with entry of the crew into the spacecraft, includes delivery of the crew to/from ISS, and ends with successful delivery of the crew to NASA after landing.
Mission Critical	Item or function that must retain its operational capability to assure no mission failure (i.e., for mission success).
Operations Personnel	All persons supporting ground operations or flight operations functions of the CTS. Examples of these personnel are listed below: Persons responsible for the production, assembly/integration/test, validation, and maintenance of flight hardware, production facilities, launch site facilities, operations facilities, or ground support equipment (GSE). Persons involved with supporting or managing the launch countdown, crew training, or mission during flight. Persons involved in post-flight recovery.
Orbit	This flight phase starts just after final orbit insertion and ends at the completion of the first deorbit burn.
Override	To take precedence over system control functions.
Pad Abort	An abort performed where the crewed spacecraft is separated from the launch vehicle while the launch vehicle remains on the launch pad. As a result, the crewed spacecraft is safely transported to an area which is not susceptible to the dangers associated with the hazardous environment at the launch pad.

Permanent Disability	A non-fatal occupational injury or illness resulting in permanent impairment through loss of, or compromised use of, a critical part of the body, to include major limbs (e.g., arm, leg), critical sensory organs (e.g., eye), critical life-supporting organs (e.g., heart, lungs, brain), and/or body parts controlling major motor functions (e.g., spine, neck). Therefore, permanent disability includes a non-fatal injury or occupational illness that permanently incapacitates a person to the extent that he or she cannot be rehabilitated to achieve gainful employment in their trained occupation and results in a medical discharge from duties or civilian equivalent.
Portable Fire Suppression System	A system comprised of one or more portable handheld fire extinguishers and access ports. These access ports allow the user to discharge fire suppressant into enclosed areas with potential ignition sources. See also 3.10.12.2 Use of Hazardous Chemicals.
Post-Landing	The mission phase beginning with the actual landing event when the vehicle has no horizontal or vertical motion relative to the surface and ending when the last crewmember is loaded on the aircraft for return to JSC.
Proximity Operations	The flight phase including all times during which the vehicle is in free flight beginning just prior to Approach Initiation (AI) execution and ending when the vehicle leaves the Approach Ellipsoid (AE).
Quiescent Docked Operations	The state of the CTS spacecraft while it is docked to the ISS with hatches open and ISS services, as called out in SSP 50808, connected and operational. From this state, the vehicle can support immediate ingress and transition into safe haven in the case of an emergency.
Recovery	The process of proceeding to a designated nominal landing site, and retrieving crew, flight crew equipment, cargo, and payloads after a planned nominal landing.
Reliability	The probability that a system of hardware, software, and human elements will function as intended over a specified period of time under specified environmental conditions.
Rendezvous	The flight phase of executing a series of onorbit maneuvers to move the spacecraft into the proximity of its target. This phase starts with orbit insertion and ends just prior to the approach initiation.
Safe Haven	A functional association of capabilities and environments that is initiated and activated in the event of a potentially life-threatening anomaly and allows human survival until rescue, the event ends, or repair can be affected. It is a location at a safe distance from or closed off from the life-threatening anomaly.
Safety	The absence from those conditions that can cause death, injury, occupational illness, damage to or loss of equipment or property, or damage to the environment.
Safety Critical	A condition, event, operation, process, function, equipment or system (including software and firmware) with potential for personnel injury or loss, or with potential for loss or damage to vehicles, equipment or facilities, loss or excessive degradation of the function of critical equipment, or which is necessary to control a hazard.
Search and Rescue	The process of locating the crew, proceeding to their position, and providing assistance.

Software	Computer instructions or data stored electronically. Systems software includes the operating system and all the utilities that enable the computer to function. Applications software includes programs that do real work for users, such as word processors, spreadsheets, data management systems, and analysis tools. Software can be Commercial Off-The-Shelf (COTS), contractor developed, Government furnished, or combinations thereof.
Spacecraft	All system elements that are occupied by the crew during the space mission and provide life support functions for the crew. The crewed element includes all the subsystems that provide life support functions for the crew.
Space System	The collection of all space-based and ground-based systems (encompassing hardware and software) used to conduct space missions or support activity in space, including, but not limited to, the integrated space vehicle, space-based communication and navigation systems, launch systems, and mission/launch control.
Stowage	The accommodation of physical items in a safe and secure manner in the spacecraft. This does not imply that resources other than physical accommodations (e.g., power, thermal, etc.) are supplied.
Subsystem	A secondary or subordinate system within a system (such as the spacecraft) that performs a specific function or functions. Examples include electrical power, guidance and navigation, attitude control, telemetry, thermal control, propulsion, structures subsystems. A subsystem may consist of several components (hardware and software) and may include interconnection items such as cables or tubing and the support structure to which they are mounted.
System	The aggregate of the ground segment, flight segment, and workforce required for crew rescue and crew transport.
Task Analysis	Task analysis is an iterative human-centered design process through which user tasks are identified and analyzed. It involves 1) the identification of the tasks and subtasks involved in a process or system, and 2) analysis of those tasks (e.g., who performs them, what equipment is used, under what conditions, the priority of the task, dependence on other tasks). The focus is on the human and how they perform the task, rather than the system. Results can help determine the hardware or software that should be developed/used for a particular task, the ideal allocation of tasks to humans vs. automation, and the criticality of tasks, which drive design decisions. Further information on task analysis can be found in JSC 65995 CHSIP, Section 4.1.
Test	A method of verification in which technical means, such as the use of special equipment, instrumentation, simulation techniques, and the application of established principles and procedures, are used for the evaluation of components, subsystems, and systems to determine compliance with requirements. Test will be selected as the primary method when analytical techniques do not produce adequate results; failure modes exist, which could compromise personnel safety, adversely affect flight systems or payload operation, or result in a loss of mission objectives. The analysis of data derived from tests is an integral part of the test program and should not be confused with analysis as defined above. Tests will be used to determine quantitative compliance to requirements and produce quantitative results.

Validation	Proof that the product accomplishes the intended purpose. May be determined by a combination of test, analysis, and demonstration.
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